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(54) **Alignment sensing apparatus**

(57) The alignment sensing apparatus includes a first component 1 and a second component 2 for positioning on opposite sides of a work piece 3, the first component having a rotating magnetic field generator, and the second component having a sensing coil 11 which, when in the rotating magnetic field, develops a signal related to the degree of any misalignment of the axes of the first and second components. The signal is presented on an oscilloscope screen in the form of a ring which decreases in size as the misalignment is itself decreased. The apparatus may be used to align a tool with a specified hole position on a surface of a workpiece, e.g. aircraft body, remote from a surface accessible to the tool.

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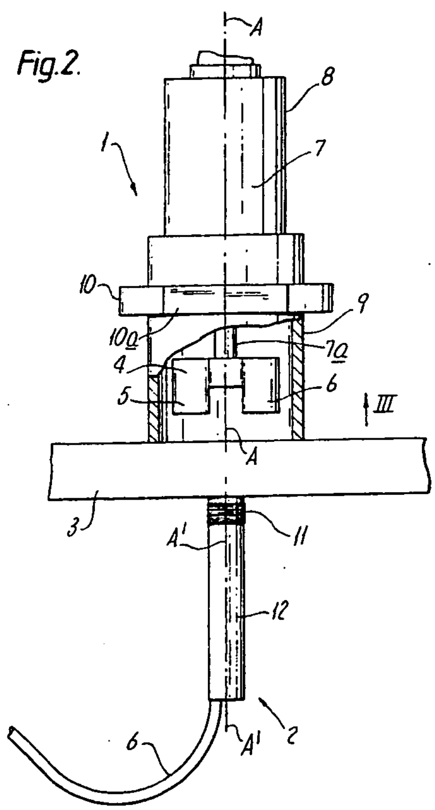
Fig.2.



The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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Fig.1.

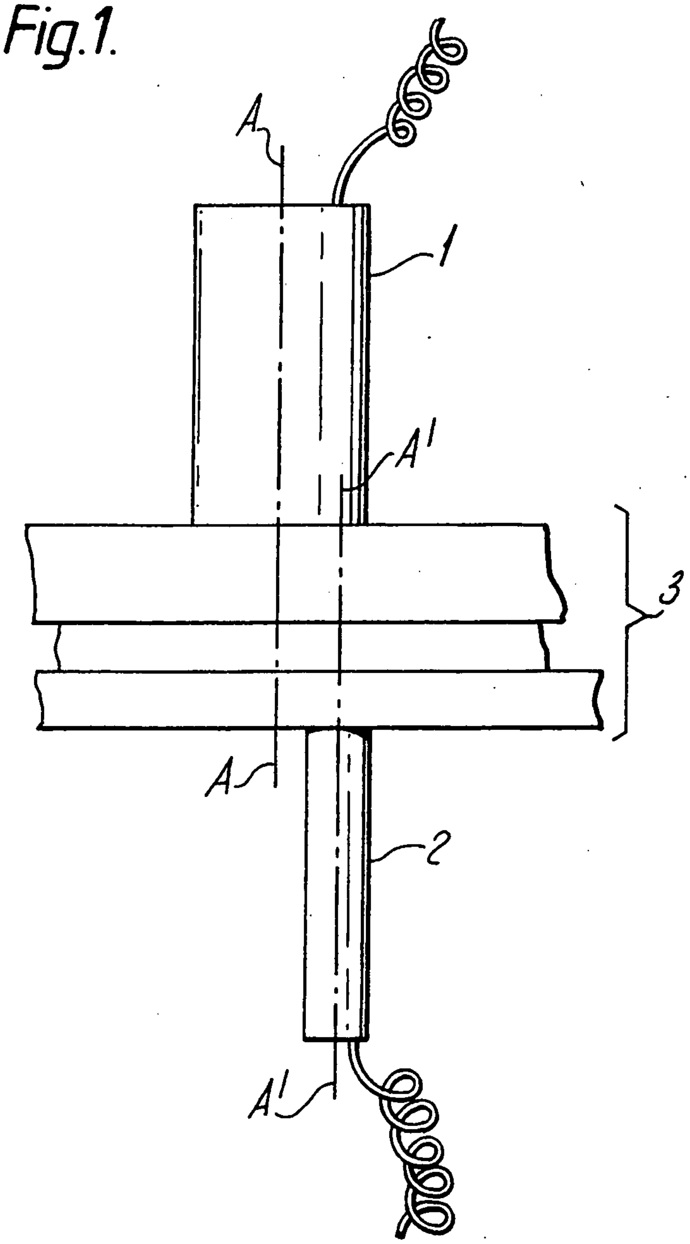


Fig.2.

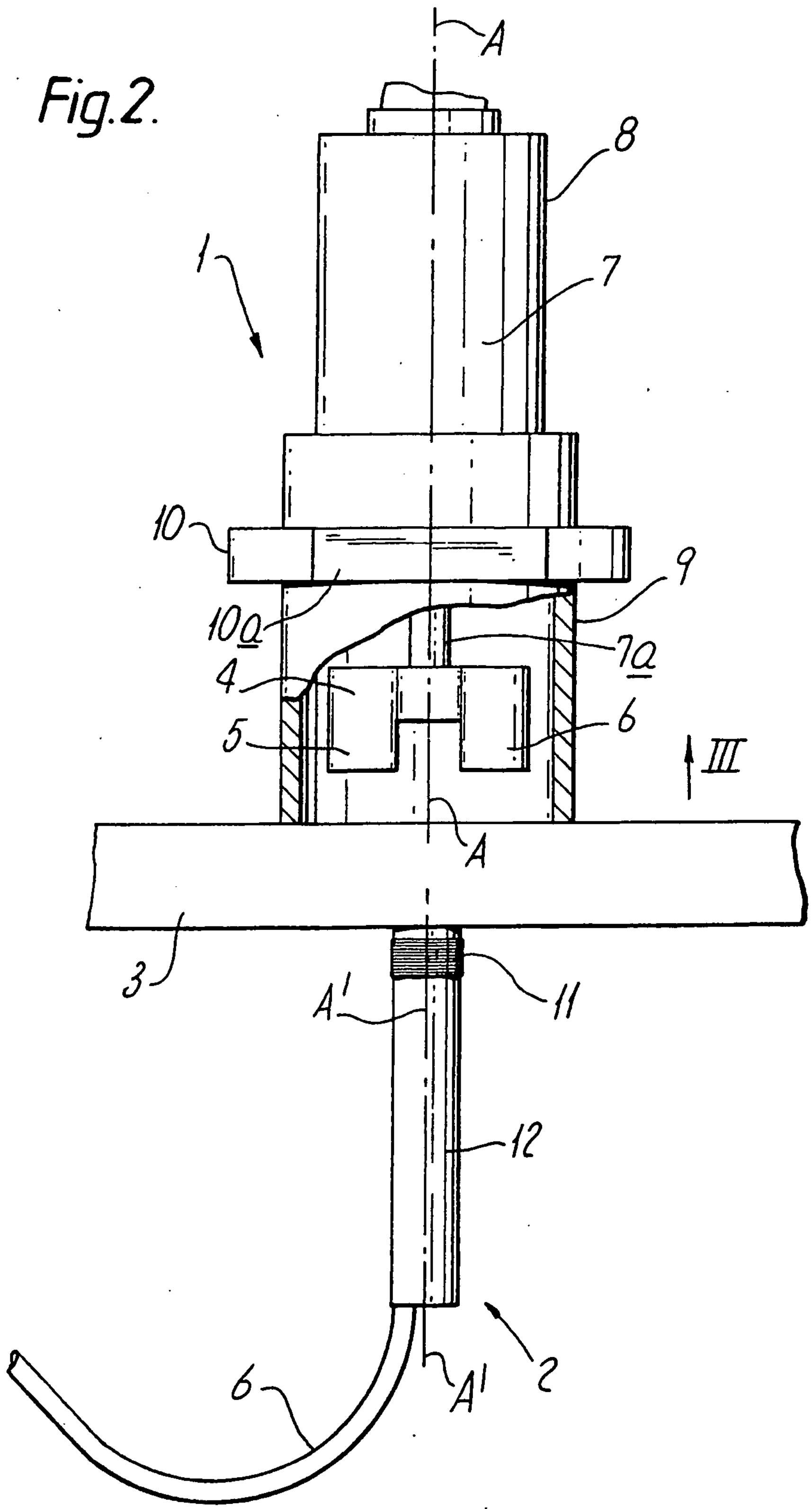


Fig.3.

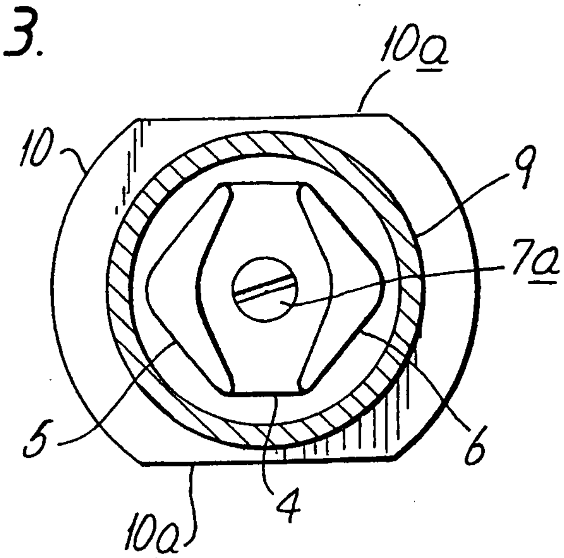
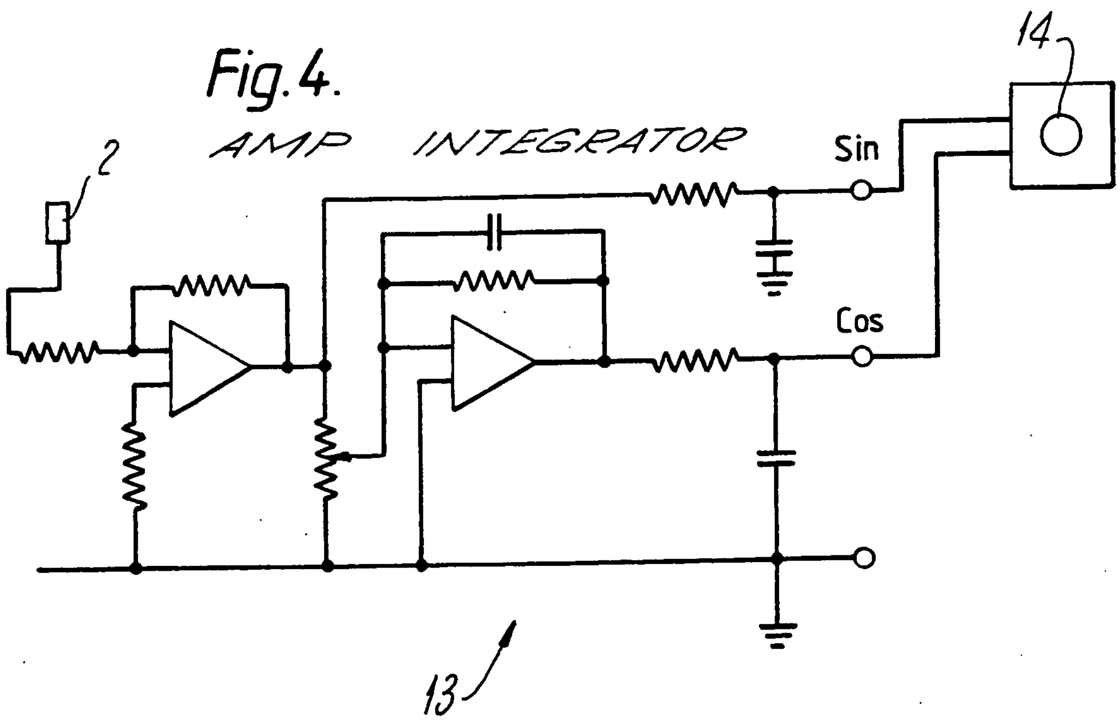


Fig.4.



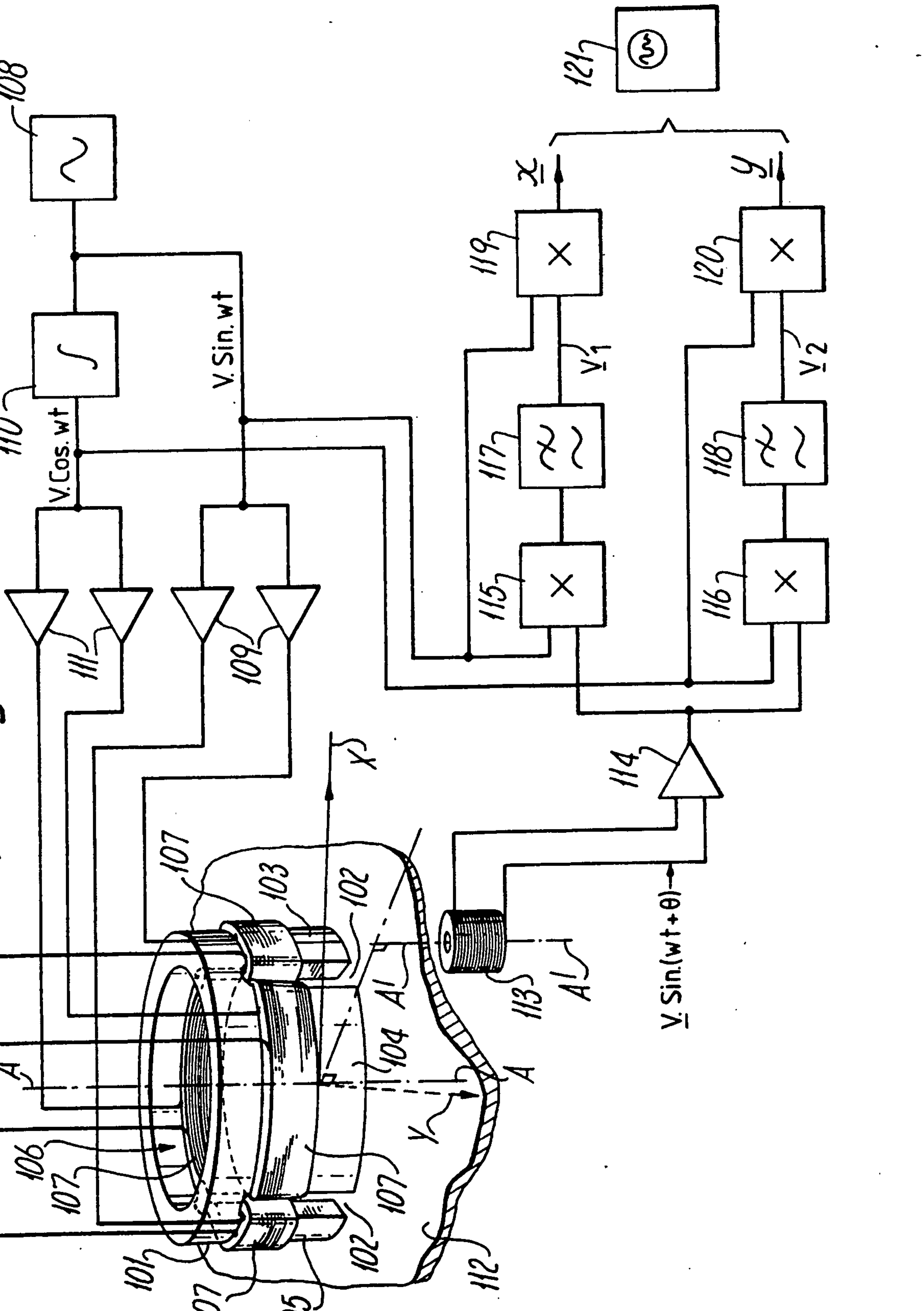

108
110
V.Cos.wt
V.Sin.wt
111
109
121
119
120
117
118
115
116
x
y
V_1
V_2
114
V. Sin.(wt+θ)
113
A'
A
X
Y
101
102
103
104
105
106
107
112

Fig.5.

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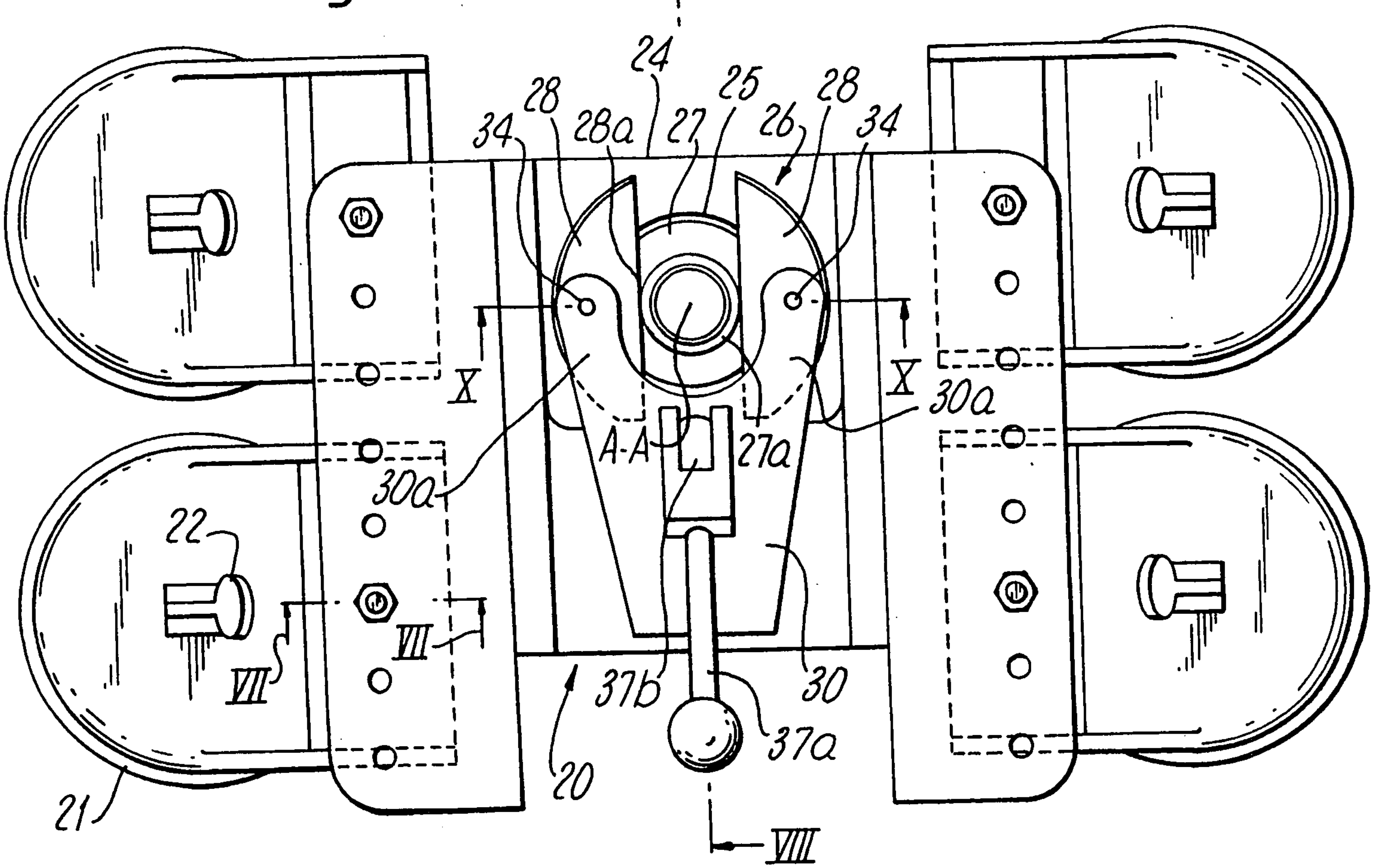
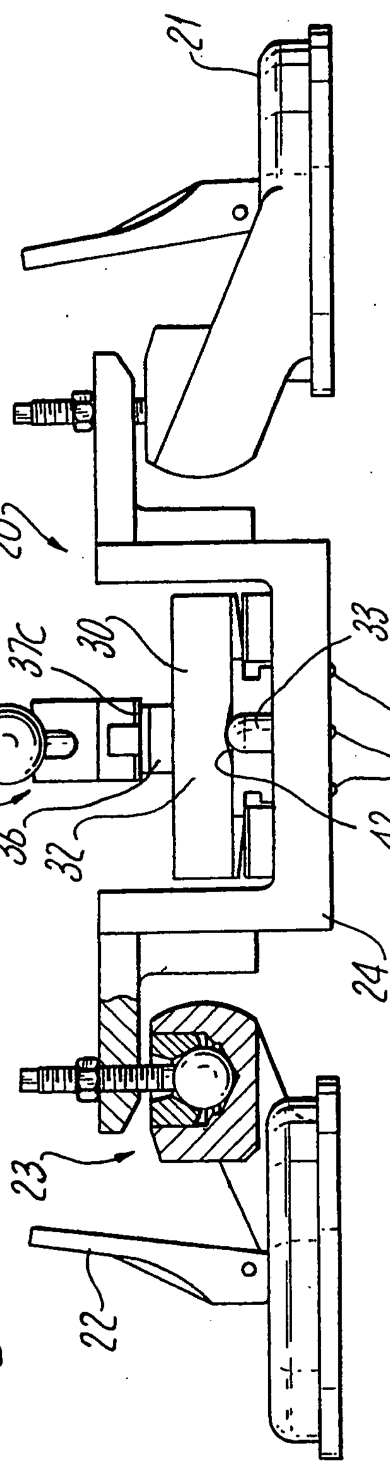
Fig.6.

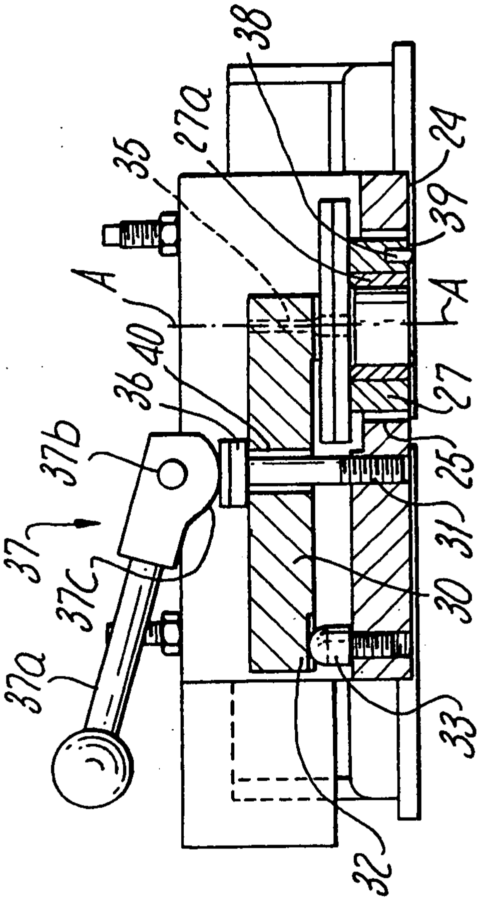


VIII
24
34
28
28a
27
25
26
28
34
X
X
30a
A-A
27a
30a
22
VII
VII
37b
30
37a
20
21
VIII



21
20
37c
30
33
37
3b
32
42
38
24
23
22

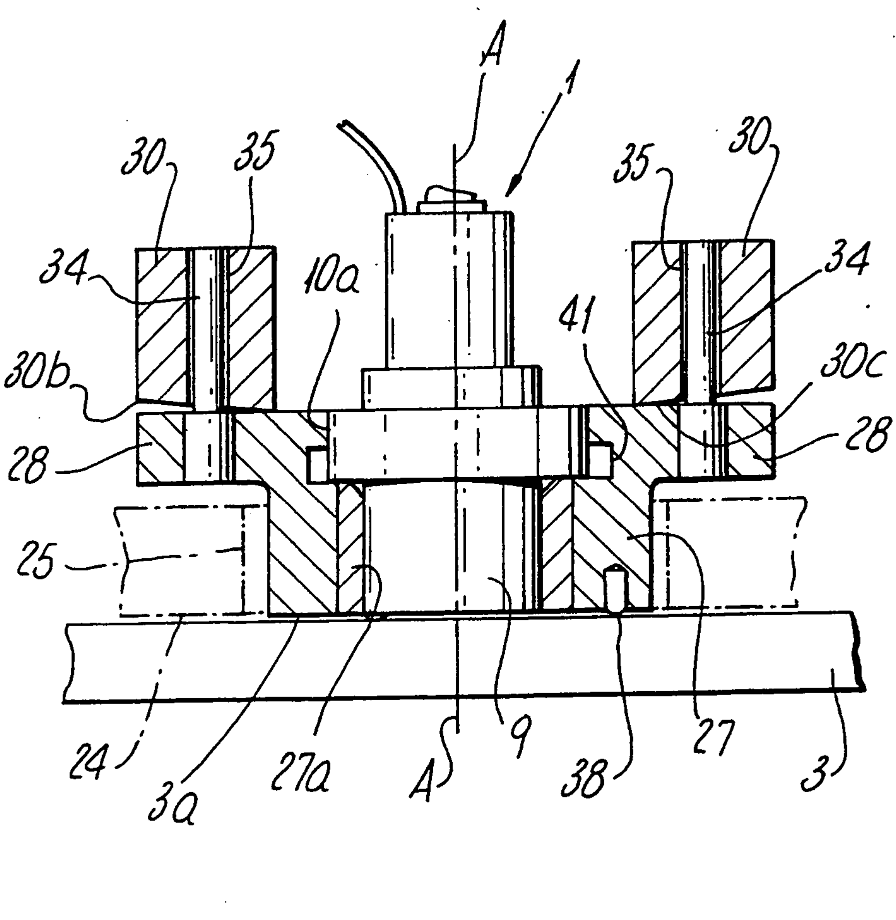
Fig.7.



38
27a
35
A
40
3b
37b
37
37c
37a
39
24
A
27
25
31
30
33
32

Fig.8.

Fig. 9.



SPECIFICATION

Alignment sensing apparatus

This invention relates to alignment sensing apparatus which can be used to aid the alignment of a machining tool with respect to a work piece.

In situations where, for example, a machining tool, say a drill, requires to form an accurately positioned hole in a work piece surface, it is customary to initiate machining on that surface. If, however, that surface is so positioned that access by the machining tool is impossible, then the hole must be initiated from a remote surface of the work piece; it is therefore difficult to ensure that the hole thus formed will align with the desired position on the work piece surface so that it will break out (if break out is required) accurately at that desired position.

Such problems occur where, for example, an aircraft wing surface member which can be of considerable thickness built up of several layers of material, requires holes to be accurately located with respect to internal members. Where drilling cannot be initiated from inside the wing due to lack of space, it must be initiated from the outside with attendant problems of ensuring break out at accurately defined positions on the internal surface region.

An object of the present invention is to provide apparatus which facilitates such alignment both in the more general field of machining tools and work pieces and in the more specific field of drilling aircraft wing surface members.

A further object is to provide apparatus which can be used on relatively large thicknesses of material.

Yet a further object is to provide apparatus wherein the conditions of alignment and misalignment are distinctly presented to an operator.

Naturally, in addition to those functional objectives, it is a further objective to provide apparatus which is relatively cheap to produce, is robust and simple to use, and is of a readily portable nature.

According to the present invention apparatus having a first component with an axis, a second component with an axis, any misalignment of the two axes when the components are generally axially spaced requiring to be indicated, includes means carried by the first component for producing a rotating magnetic field which sweeps around the axis of the first component and extends towards the second component, means carried by the second component responsive to the rotating field to produce a signal related to the degree of misalignment of the two axes, and means for accepting and indicating the signal so produced such that any misalignment of the two axes can be at least reduced.

By this arrangement, one component can be placed on a remote side of a work piece at a point where a drilled hole must accurately break out, and the other component can be movably placed on an accessible side of the work piece where drilling can take place. The latter component can be moved until the apparatus indicates that precise alignment has been reached.

rotating magnetic field is a rotating permanent magnet. In this case the magnet is positioned such that its north and south pole regions are symmetrically disposed for rotation about the axis of the first component.

Alternatively, said means comprises static multipole electromagnetic means with polyphase windings.

Irrespectively, the produced signal is in the form of an alternating voltage of diminishing amplitude as misalignment of the axes is removed.

In each case the means in which the signal is produced is a winding or relatively small diameter.

Conveniently, the indicating means includes signal resolving means and display means such that any misalignment of the axes is displayed as an annulus which decreases in size. One embodiment of the invention is now described with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic side view of a work piece, in this case a sheet of material, with components of apparatus according to the invention positioned thereon,

Figure 2 is a similar view of one embodiment of the apparatus,

Figure 3 is a view on Arrow III of Figure 2,

Figure 4 is a schematic diagram of circuitry associated with the embodiment of Figure 2,

Figure 5 is a view of part of an alternative embodiment of the apparatus, together with a schematic diagram of associated circuitry,

Figure 6 is a plan view of a jig for use in aiding alignment of the components of the apparatus and for subsequently enabling drilling in the precisely aligned position,

Figure 7 is an elevation of the jig partly sectioned along line VII - VII of Figure 6,

Figure 8 is a cross-sectional view on line VIII - VIII of Figure 6, and

Figure 9 is a cross-sectional view on line X - X of Figure 6.

Referring to Figure 1, alignment sensing apparatus includes a first component 1 and a second component 2 which components can be positioned on opposite sides of a work piece 3, in this case several sheets of carbon fibre composite material.

The first component 1 includes means for providing a rotating magnetic field, the rotation taking place about an axis A - A. The magnetic field extends downwards, as drawn, towards the work piece. The second component 2 includes means sensitive to the rotating magnetic field, the means lying symmetrically with an axis A' - A'. This latter axis A' - A' and the axis A - A can be aligned one with the other by relative movements of the components.

Referring now to Figures 2 and 3 which illustrate one embodiment of the invention, the first component includes a permanent horseshoe magnet 4 having pole regions 5 and 6 disposed symmetrically about the axis A - A. The magnet 4 is rotated about this axis A - A by an electric motor 7 carried within a housing 8. The magnet 4 is conveniently carried on a shaft 7*a* protruding from the motor 7.

A cylindrical sleeve 9 of non-ferrous material is

this and the sleeve itself extends below the level of the magnet (as drawn) towards the work piece and facilitates the holding of the axis A - A perpendicular to the local surface of the work piece. As drawn this localised surface is shown flat, but naturally it could be contoured and if substantially so, the work piece contacted edge of the sleeve can be suitably shaped to marry up with the local contour.

The sleeve 9 has a shoulder region 10 with flats 10*a* for location purposes to be described.

The second component 2 includes a sensing coil 11 wound around a rod-like former 12 symmetrically about the axis A' - A'. This second component 2 can be held but is preferably clamped in the perpendicular position shown at the point where it is desired to effect break-out of the drill. The clamp, where used, preferably makes use of adjacent structure for location purposes.

An A.C. signal is induced in the coil 11 when it lies within the rotating magnetic field and this is passed to an amplifier and integrating circuit 13, shown generally in Figure 4, and from which twin outputs in the form of parallel sine and cosine signals respectively are passed to an oscilloscope 14 for display to an operator.

The A.C. signal from the coil 11 can be merely amplified and displayed on the oscilloscope screen as a sine wave trace of diminishing amplitude as precise alignment of the axes A - A and A' - A' is approached. On precise alignment a straight line trace is displayed.

Such a sine wave display is found to be generally acceptable by an operator but in practice some difficulty is found in actually reading from the display when precise alignment is effected. Accordingly an improved display, found by a majority of operators to greatly facilitate alignment, is produced by the circuit 13. By supplying the A.C. signal in both sine and cosine form to the oscilloscope an annular trace is presented, in this case a circle whose diameter reduces as non-alignment is reduced. On precise alignment, an infinitely small circle is displayed which in practice appears as a pin-point.

The electric motor and rotating magnet of the first component may be replaced by a polyphase electromagnetic arrangement which is operable for producing a rotating field although the arrangement itself is fixed. For example, as shown in Figure 5, the wall of a hollow, cylindrical ferrite core 101 has apertures 102 to define four lobes or poles 103 to 106, the pole 106 being partly hidden, in the figure, behind pole 104. Each pole has a winding 107. A signal V.sin ωt formed by a sine-wave oscillator 108 is fed *via* respective drive amplifiers 109 to the coils 107 on two opposite poles 103 and 105, these coils being connected in antiphase so that the field components produced by the respective poles are also in antiphase. The signal V.sin ωt is also integrated by integrator 110 to produce a signal V.cos ωt which signal is fed *via* respective drive amplifiers 111 to the coils 107 on the remaining two poles 104 and 106. The windings on poles 104 and 106, like the windings on poles 103 and 105 are connected to produce antiphase field components. The resultant field of the four components is a field orthogonal to the core axis A - A and rotating about that axis at a speed ω radians/sec. This speed depends, of course, on the frequency of the oscillator 108 ($\omega = 2\pi f$) which frequency might be say 10 KHz i.e. well outside the range of mains hum.

It will be appreciated that, compared with the case where a rotating magnet is used to form the rotating field, the Figure 5 arrangement may permit, more conveniently, a higher speed of field rotation while any inaccuracies due to motor bearing tolerance in the rotating magnet embodiments are obviated.

As before, the position of the field axis is sensed from the opposite side of the workpiece 112 by a pick-up coil 113. Since, in this embodiment, the derive signals V cosωt and V sin ωt are available, they may conveniently be used in the pick-up coil signal processing circuit to drive information on the direction in which the pick-up coil should be moved in order to achieve alignment of coil and core.

If the pick-up coil were displaced from axis A - A along the common axis X of the V.sin ωt field components produced by poles 103 and 105, the pick-up coil signal would be in phase with V. sin ωt. Correspondingly, if the coil were displaced from axis A - A along the axis Y of the V. cos ωt components produced by poles 104 and 106, the coil signal would be in phase with V. cos ωt or V. sin (ωt + 90°). Aligned, as shown, along an intermediate axis at angle θ to axis X, the coil signal is thus v. sin ($\omega t + \theta$). The amplitude v of the signal varies with the distance from axis A - A.

The pick-up coil signal processing circuit comprises a switchable-gain, low noise pre-amplifier stage 114 for amplifying the pick-up coil signal v. sin ($\omega t + \theta$) and two analogue multipliers 115 and 116 each arranged to multiply the amplified pick-up coil signal by a respective one of the signals V. sin ωt and V. cos ωt from the core drive circuit. The outputs of the multipliers are low-pass filtered by respective filters 117 and 118 to give two d.c. levels v_1 and v_2 respectively representing the average full-wave rectified values of va and vb in the following equation:-

$$v.\sin(\omega t + \theta) = va.\ \sin \omega t + vb.\ \cos \omega t.$$

The levels v_1 and v_2 thus represent the Cartesian co-ordinates of the position of the pick-up coil 113, in terms of angle only, with respect to the field axes X and Y. The amplitudes of v_1 and v_2 are proportional to the inverse square of the distance of the coil axis A' - A' from the core axis A - A.

Instead of the multipliers 115 and 116, two phase sensitive rectifiers (not shown) controlled by respective square-wave signals derived from the core drive signals V. sinωt and V. cosωt may be used to rectify the signal from pre-amplifier stage 114 prior to filtering by filters 117 and 118.

In order to produce a Lissajou's figure on the screen of an oscilloscope 121 as in the previously described embodiments, the *d.c.* levels v_1 and v_2 are passed to respective ones of two further analogue multipliers 119 and 120 along with respective ones of the core drive signals, the outputs of the multipliers being fed to the x and y beam deflection amplifiers of the oscilloscope. The resultant trace on

the oscilloscope screen is an ellipse, when the coil and core are not aligned, shrinking to a tiny circle when such alignment is achieved.

The first component of the apparatus can be moved entirely by hand to find the alignment position but then the operator is faced with the problem of fixing the position in readiness for drilling.

This is most conveniently done using a jig to locate the first component allowing fine adjustment of its position during the alignment procedure, the jig also having the facility to fix the required drilling position such that the first component may be removed from the jig and a suitable drill inserted in its place.

Figures 6, 7, 8 and 9 show such a jig comprising a carriage 20 and a fine adjustment assembly 26 housed in a central depending part of the carriage.

The carriage is of generally channel-shaped cross section and is supported by four limpets 21 each attached to carriage 20 by a respective universal joint 23. Each limpet 21 comprises sucker means which may be selectively actuated by rotating a lever 22 to attach the carriage to the surface to be drilled. When so attached the lower surface 24 of the central depending part of the carriage 20 is maintained approximately parallel to, and at a small distance from, the surface to be drilled. The universal joints 23 allow such positioning of the carriage 20 even when the surface to be drilled is of complex or composite curvature.

The fine adjustment assembly as previously described is housed in the central depending part of the carriage 20, and has the function firstly of receiving the first component or drill attachment and secondly, in a first unclamped state, of allowing small lateral movements of the first component during alignment and, in a second clamped state, of fixing the alignment position found, ready for drilling. The fine adjustment assembly comprises two basic parts:

(i) a reception assembly for receiving the first component, and

(ii) a clamping assembly for clamping the reception part relative to the jig and therefore also relative to the surface to be drilled.

The reception assembly comprises a cylindrical housing 27, which fits with a predetermined clearance into an aperture 25 of the central depending part of carriage 20 and two bearing flanges 28 integral with housing 27 which are each preferably in the form of achordal segment of a circle as viewed in plan. The housing 27 is fitted with a co-axial machined bush 27a for receiving the sleeve 9 of the first component and the lower surface 38 of housing 27 contains three rubber pips 38 equispaced on a certain pitch circle diameter for contacting the surface to be drilled to ensure that drilling axis A - A will be perpendicular to the surface to be drilled.

The clamping assembly comprises a clamping plate 30 pivotally supported at its rearward extremity on a hemispherical pivot pin 33 and bearing at its forward extremity on the flanges 28 of the reception assembly, and pressure application means interconnected with the clamping plate 30 including a clamping lever assembly 37 wherey clamping pressure may selectively be applied to retain the reception assembly in its determined position.

Forwardly extending arms 30a of the clamping plate incorporate clearance holes 35 for engaging upstanding spigots 34 of flanges 28. The undersurface of arms 30a are chamferred at 30b to provide localized clamping pressure areas 30c engaging the upper surface of flanges 28.

The spigots 34 ensure that, when the reception assembly is moved during the alignment procedure the clamping plate 30 is maintained in the same position relative to the flanges 28. Movement of the clamping plate 30 on the carriage is accommodated by the hemispherical pivot pin 33 registering with a longitudinally extending recess 42, permitting longitudinal displacement of the clamping plate 30, as well as angular displacement about the axis of pivot pin 33 in the horizontal plane within pre-determined tolerances.

To accommodate such movement and yet still allow application of clamping pressure when required, the clamping plate incorporates a longitudinally extending slot 40 to house the mounting for the clamping lever assembly 37. This assembly comprises a cammed lever 37a pivotally attached at 37b to a vertical post 31 engaging the carriage 20 and passing through the elongate slot 40. A pressure collar 36 slidable along the post 31 is sandwiched between the clamping plate 30 and a cam surface 37c of the clamping lever 37a.

The operation of the jig in conjunction with the apparatus positioning device will not be described.

First, the second component 2 is clamped on to one side of the work piece 3 at the desired location for the hole to be drilled. The jig is then placed on to the other side of the work piece such that the axis of bush 27a is approximately coincident with that of the second component A' - A'. Levers 22 of the limpets 21 are then rotated to attach the jig to the surface. The sleeve 9 of the first component 1 is then inserted into the bush 27a in which it is a sliding fit, the flats 10*a* of the sleeve registering with the inward facing linear surface 28a of bearing plates 28 such that the first component cannot rotate relative to the reception part of the fine adjustment assembly. Then, with clamping lever 37a in a non-clamping position, the apparatus is energised. The operator may then move the first component across the surface to be drilled within the limits defined by the abutment of the radially outer surface of housing 27 on the inner surface of aperture 25. When alignment of second component 2 and first component 1 has been found using the procedure previously described, the clamping lever 37 is rotated to the clamping position. The housing 27 is now fixed in aligned position on the surface to be drilled. The apparatus may then be de-energised and removed from the jig and a drill attachment inserted in its place once the second component 2 has been removed from the other side. The drill is conveniently provided with a cylindrical locating sleeve identical externally to that of the sleeve 9 of the first component with the exception that the drill sleeve is provided with a taper-lock facility, a tapered flange locating in slots 41 of the

bearing plates 28, and twisting of the sleeve locking the drill in place to provide a more rigid clamping necessary for the drilling operation.

The clearances allowed between the parts of the fine adjustment assembly allow the housing 27 to be clamped perpendicular to the surface to be drilled when the lower surface 24 of the carriage 20 is not necessarily parallel to the surface. The rubber pips 38 ensuring correct bedding of the housing 27 on to the surface. Pips 38 may optionally be replaced by an O-ring recessed concentrically into bearing surface 39.

The jig as described is highly portable and may be attached to vertical, horizontal and positively or negatively inclined surfaces.

CLAIMS

1. Alignment sensing apparatus having a first component with an axis, a second component with an axis, any misalignment of the two axes when the components are generally axially spaced requiring to be displayed, includes means carried by the first component for producing a rotating magnetic field which sweeps around the axis of the first component and extends towards the second component, means carried by the second component responsive to the rotating field to produce a signal related to the degree of misalignment of the two axes, and means for accepting and indicating the signal so produced such that any misalignment of the two axes can be at least reduced.

2. Apparatus according to claim 1, wherein the indicating means includes signal resolving means and display means such that any misalignment of the axes is displayed as an annulus which decreases in size as misalignment is removed.

3. Apparatus according to claim 1 or claim 2, wherein said first component includes a rotating permanent magnet.

4. Apparatus according to claim 3, wherein the magnet has its pole regions symmetrically disposed for rotation about the axis of the first component.

5. Apparatus according to claim 1 or claim 2, wherein said first component includes multi-pole electromagnetic core means with polyphase windings for producing a rotating field which the core means itself remains static.

6. Apparatus according to claim 5, wherein the core means comprises a hollow cylindrical member of which the wall has recesses extending therein from one end of the member, the wall-portions between the recesses having respective windings thereon and forming the poles of the core means.

7. Apparatus according to claim 5 or claim 6, including a.c. supply means connected to said core means for supplying thereto a two-phase winding supply signal of which the components are in phase quadrature, the core means being responsive to this supply signal to produce said rotating field, and said indicating means including signal resolving and filtering means which is connected to said second component for receiving the output signal therefrom and to said a.c. supply means for receiving the winding supply signal components and which is operable for forming two d.c. signal levels representing the amplitudes of respective resolved components of said output signal in phase with respective ones of said winding supply signal components.

8. Apparatus according to any one of the previous claims, wherein the second component includes a winding of relatively small diameter.

9. Apparatus according to any one of the previous claims further including adjustable location means for one said components, said location means including receiving means for receiving alternatively said one of said components or machining tool means, body means for carrying the locating means, adjustable means for temporarily but rigidly fixing the body means to a workpiece, guide means allowing limited relative movement between the receiving means and the body means, and anchoring means for anchoring the receiving means to the body in a desired position such that said one of said components can be replaced by machining tool means without altering the desired position.

10. Apparatus according to claim 9, wherein the receiving means is of generally cylindrical form with a longitudinal bore for accepting one of said components or machining tool means, and the guiding means is in the form of an annulus in the body member through which the receiving means protrudes.

11. Apparatus according to claim 10, wherein the anchoring means includes a clamping having a bifurcated clamping member, and the receiving means carries shoulders spaced one to each side of the longitudinal bore on which the bifurcations locate to effect clamping.

12. Apparatus according to any one of claims 9 to 11, wherein the means for fixing the body means to a workpiece include suction devices.

13. Apparatus substantially as described with reference to Figures 1, 2, and 3 of the accompanying drawings.

14. Apparatus substantially as described with reference to Figures 1 and 5 of the accompanying drawings.

15. Apparatus substantially as described with reference to Figures 1, 6, 7, 8 and 9 of the accompanying drawings.

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